

**Mars Pathfinder Active Heat Rejection System: Successful Flight Demonstration of a
Mechanically Pumped Cooling Loop**

Gajanana C. Birur and Pradeep Bhandari
Thermal and Propulsion Engineering Section
Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

ABSTRACT

One of the new technologies successfully demonstrated on the recent Mars Pathfinder mission was the active Heat Rejection System (I-IRS). This system consisted of a mechanically pumped cooling loop which actively controlled the temperatures of the various parts of the spacecraft. A single phase Refrigerant 11 liquid was mechanically circulated through the lander and cruise electronics box heat exchangers and transferred the excess heat to an external radiator on the cruise stage. This is the first time in the unmanned spacecraft history that such an active heat rejection system has been used on a long duration spacecraft mission. Pathfinder was launched in December 1996 and landed on Martian surface on July 4, 1997. The system functioned flawlessly during the entire seven months of flight from Earth to Mars.

The HRS consisted of the Integrated Pump Assembly (I PA), radiators, electronics box heat exchangers, filter, and associated tubing was designed, fabricated, installed and tested on the Pathfinder spacecraft from June 1994 to June 1996. The HRS operated continuously throughout the entire seven months of cruise to Mars. The IPA, which is the heart of the HRS, circulates and controls the working fluid in the HRS during this cruise in order to transfer excess heat from the various spacecraft parts to the radiator.

The HRS was designed to meet the following key Pathfinder system requirements : 1) a heat transfer rate of 90 to 180 Watts, 2) a total mass of less than 18 kg (including 8 kg for the I PA), 3) a maximum power consumption of 10 Watts, 4) a life of two years of continuous operation, and 5) redundancy for the active components of the I PA. There were also thermal and hydraulic requirements for the working fluid operating pressures, flow rates, pressure drops, radiator bypass flow rates, and leakage rates.

The major elements of the IPA are two centrifugal pumps, an accumulator, two thermal control valves, four check valves, and the motor control electronics. Only one pump/thermal control valve is needed to circulate the Refrigerant 11, the working fluid, in the system. The other set of pump/thermal control valve acts as a backup. The pump was rated to produce 6 psid at a rated flow of 0.2 gpm of Refrigerant 11 in the -30 to +30 C range. The motor control electronics were designed to operate the pump motor at the rated performance over an input power of 27 to 36 Vdc. The maximum operating pressure of the system was 95 psia. The accumulator keeps the operating pressure 30 psi above the saturation pressure of Refrigerant 11 at the operating temperature.

The performance of the HRS, specifically the IPA, was carefully monitored during the entire spacecraft ground operations. The thermal, electrical, and hydraulic performances of the HRS have more than satisfied the Pathfinder requirements. The HRS performance was continuously monitored during the entire flight to Mars. The HRS kept the spacecraft temperatures within the requirements throughout the flight. The cruise stage of the spacecraft which contained the IPA and the radiator was severed from the rest of the spacecraft just before the entry into Martian environment. The working fluid was vented out using the high pressure gas in the accumulator. Based on the telemetry, the spacecraft nutation increase due to this venting was less than 2 degrees and did not affect the spacecraft navigation into the planet.

A life test on a mechanically pumped cooling loop was also conducted simultaneously with the flight cooling loop system fabrication and actual flight. The life test loop consisted of the engineering model of the flight mechanical pump and include several elements of the flight HRS. The life test loop was opened after 13,000 hours of continuous operation of the pump. The initial chemical analysis of the working fluid indicates no corrosion particles in the system. Further, the moisture content of the Refrigerant 11 stayed at the same level as at the start of the test. No corrosion of the aluminum tubes have been noticed. The mechanical pump is currently being disassembled and a physical examination of the pump will be made to see the degradation of the hydrodynamic journal bearings and impeller.

Many lessons were learned during the ground and flight operation of the HRS. Several modifications were made on the operation of the HRS based on these lessons. Since it is the first time that such a mechanically pumped cooling loop was flown on a deep space mission, there is a lot of interest in its performance and reliability. The only other space application of the mechanically pumped loops has been for the Space Shuttle where they were used for a short duration (less than one month at a time) flights.

The paper will present the performance of the mechanically pumped cooling loop during the ground and flight operations. Based on the lessons learned from this experience, recommendations on the design and operation of the pumped cooling loops for future space missions will be made.

References:

- 0196-1676
1. G. Birur, P. Bhandari, M. Gram, and J. Durkee, "Integrated Pump Assembly - An Active cooling System for Mars pathfinder Thermal Control," Paper No. 961489, 26th International Conference on Environmental Systems, Monterey, California, July 8-11, 1996.
 - 0196-1676 2. P. Bhandari, G. Birur, and M. Gram, "Mechanical Pumped Cooling Loop for Spacecraft Thermal Control," Paper No 961488, 26th International Conference on Environmental Systems, Monterey, California, July 8-11, 1996.